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ABSTRACT

This study was conducted to examine the basic conceptual knowledge and understanding of physics possessed by students enrolled in introductory physics, mechanics and waves and optics courses at John Abbott College (JAC). The study used a 36-item multiple-choice test of physics preconcepts developed by Halloun and Hestenes. The Halloun and Hestenes test was administered to 510 JAC students and to 57 high school students at a neighboring feeder high school, and results were compared with Halloun and Hestenes' results of an administration of the test to high school, university, and college students in Arizona. Results were also compared with those of Desautels, who used an 11-item test to assess francophone two-year college students' preconcepts and understanding of uniformly accelerated motion. Study findings included the following: (1) the conceptual knowledge of the Quebec high school students was consistent with that of the Arizona high school students; (2) conventional instruction did little to improve JAC students' and Arizona college students' understanding of mechanics concepts; (3) the mechanics scheme held by most JAC students was comparable to that held by students in other countries; (4) in Quebec, language of instruction did not affect the development of students' understanding of the conceptual framework of mechanics; and (5) Halloun and Hestenes' test could not serve by itself as a placement test for the mechanics course at JAC. (WJT)

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# Preconcepts in Physics

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**Report to the John Abbott College Research and Development Committee**
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## ABSTRACT

The multiple choice test of Halloun and Hestenes [Am. J. Phys. 53 1043, 1985] has been used to examine the mechanics preconcepts of physics students at John Abbott College. The test has been used as a pre-test and as a post-test. Our results, obtained by administering the test to 850 students enrolled in courses Introductory Physics 111, Mechanics 101, Waves and Optics 301, and to grade eleven high school students, have been compared with those of high school, university, and college students in Arizona as reported by the authors of the test. The scores have also been compared with the results of Desautels (College de Rosemont Rapport * 6746-0128) who examined the preconcepts francophone CEGEP students, enrolled in mechanics 101, and waves and optics 301, held in the area of uniformly accelerated motion. The correlations between score in the test and final grades in the introductory physics course and the mechanics course were found to be 0.27 and 0.21 respectively indicating that the test in itself could not serve as a placement test for incoming students.

## INTRODUCTION

As children grow up in this world they play. As part of this play they run and jump, they throw balls into the air, they watch objects slide and fall.

Developmental psychologists such as Piaget posited that as children undertake concrete physical actions they use their experiences to build mental models and to organize these models into a self consistent integrated knowledge structure. Some of the schemes that children develop differ substantially from those that a modern physicist uses.

For example; Newton's laws of motion are the basis for classical mechanics. The first law states;

"Every body persists in its state of rest or of uniform motion in a straight line unless it is compelled to change by forces impressed on it".

However, most people suppose that;

"constant motion requires constant force".

It is only when, and if, they realise that friction is a force to be accounted for like any other that they come to accept Newton's view.

Such alternate frameworks have been observed among children and adults in many countries in many cultures (Gunstone and Watts 1985); and were espoused by both medieval and Greek philosophers (Cohen 1985); for example Aristotle's law of motion can be expressed as,

"the greater the force the greater the speed"

Children, students, and adults possess stable, self consistent schemes that explain for them how the world works. Such frameworks are deeply held: indeed when shown by a laboratory experiment, that their scheme does not explain events as well as that of the physicist, many will prefer to hold two schemes in parallel; the one that works in the laboratory for use in the laboratory, and the one that is used in their "real" world and which they feel most comfortable with: no contradiction is seen or admitted.

## AIM OF THE PROJECT

The original aim of this project was to develop a written test to determine the preconcepts of physics students at John Abbott College because, as has been suggested,

"The most important single factor influencing learning is what the pupil already knows. Ascertain this and teach him accordingly ".

Ausubel (1978)

A test of the initial knowledge state of college physics students which has recently been developed was found to meet the needs of this project, and would also provide comparative data. (Halloun & Hestenes 1985) This report describes the results obtained, and compares the local findings with those of the authors of the test. The results are also compared with those of Desautels (1985).

## THE HALLOUN and HESTENES PROJECT

Halloun and Hestenes developed a 36 question multiple choice test designed to assess the preconcepts of physics students; the test has been used as a placement test, as a pre-test, and as a post-test.

In 1986 Hestenes gave me permission and encouragement to use the test. He also provided additional material on the test and on an accompanying mathematics test.

Halloun and Hestenes first devised a test that required written answers; from an examination of both the right and the wrong answers they selected the most prevalent misconceptions as the basis for the distractors of the multiple choice test. The test was validated by physics professors and graduate students who agreed on the correct answers. Subsequently twenty two students who had written the test were interviewed and it was confirmed that they had understood both the questions and the answers. Finally the questionnaires of thirty one students who, after writing the test, had done very well in their physics course were examined and no common misunderstandings that might be due to the wording were found.

The questionnaire has been used by more than one thousand students at Arizona State University. Both the physics and the mathematics questionnaires have also been used by Hake (1987) at Indiana University in Bloomington, and by others (Van Zee 1987).

## THE DESAUTELS PROJECT

Desautels (1985) developed an eleven question written test designed to identify and assess the preconcepts and understanding that students had about "uniformly accelerated motion". The test was used both as a pre-test, to determine the need for, and as a post-test, to measure the results achieved by, an interactive computer assisted instruction module designed to teach the correct use and understanding of the concepts of uniformly accelerated motion. This work was supported by DGEC under the PROSIP programme with the title "Le dévelopment de l'intuition du movement uniformément accélére grâce aux simulations interactives". He administered his test to 288 students at Collège de Rosemont in 1984 and in 1985.

His work was of direct interest because the results of tests given in physics courses on mechanics and on waves and optics at Collège de Rosemont could be compared with the results obtained by students in similar courses at John Abbott College.

The questions which Desautels used are related to the work of Galileo, as are many of the questions used in other tests, both written and in the context of diagnostic interviews, such as that of Clement (1981). They were similar to ones I had planned to use. What was novel about his test, however, was that each question was in three parts.

Each question consisted of a sketch or a paragraph that established the scenario or situation. Following this description there were three questions the first two of which were designed solely to determine whether or not the student had understood what was stated and what was asked. The third question tested understanding of the concept.

The test provides additional results from Québec students that can be compared with those of American students as found in tests such as that of Halloun and Hestenes.

## THE JOHN ABBOTT PROJECT

The Halloun and Hestenes test was administered to a total of 510 students at John Abbott College, and to 57 high school students at a neighboring feeder high school.

The following research questions were asked:

1. How does the average score of a high school physics class in Québec compare with the score of a high school class in Arizona, as reported by Halloun and Hestenes?
2. How does the average score achieved by English speaking college students in Québec compare with the average score of students entering university in Arizona?
3. What kinds of thinking and mental models do students reveal when interviewed?
4. How do the results compare with those of Desautels?
5. If the test were to be given to students immediately prior to their enrollment at John Abbott College, would the test provide information about which physics course would be most suitable for them, ie could this test be used as a placement test?

## METHODS AND PROCEEDURES

### THE JUNIOR COLLEGE SYSTEM IN QUEBEC

The educational system in Québec differs from that in most Provinces and States.

The Collèges D'Enseignement Général et Professionnel, or General and Vocational Colleges, ( CEGEP's) were created by removing grade 12 from the high schools and "first year" from the universities and placing these two years of post secondary education in a new system of colleges. All students thus complete high school after grade eleven. Those seeking higher education go on to CEGEP where, in most classes, there is a mixture of students enrolled in both two year pre-university programs and three year vocational programs. Currently there are about 68 000 students enrolled in the 42 colleges of the CEGEP system; John Abbott college has 5000 students, about 1200 of whom are taking physics in any semester.

This study is concerned with students in the pre-university physics programme. This programme is a three semester sequence of courses, Mechanics 101, Electricity and Magnetism 201, and Waves and Optics 301. Calculus is used where appropriate. The courses cover, over the three 75 hour semesters, most of the material found in traditional "first year" university physics courses. The current text, Serway - PHYSICS for SCIENTISTS and ENGINEERS (2nd edition 1986), is the most widely used of its type in North America; in the past such other standard books as Sears, Zemansky, and Young - UNIVERSITY PHYSICS (1987), and Tipler - PHYSICS (1982), have been used.

There are two physics courses at high school; regular physics and a higher level course using the methodology of the Physical Sciences Study Committee or PSSC course ( Haber-Schaim 1976).

Students who have obtained at least 80% in the province-wide grade eleven PSSC exam, or are above the 80th percentile in the regular exam can enter directly into mechanics 101 at John Abbott College. Students who pass high school physics but have not satisfied the above criteria are required to follow introductory physics 111. This is a one semester, algebra based course designed to strengthen laboratory skills, algebra and trigonometry as used in physics, and the use of graphing as a tool in solving problems and representing relationships . Much time is spent on problem solving. Currently the course material is 5 weeks of current electricity, 5 weeks of optics, and 5 weeks of kinematics; the text is Tipler- COLLEGE PHYSICS (1987).

Class sizes at John Abbott College are small, between 30 and 45 students in physics courses. All the physics courses involve three hours of lecture and two hours of laboratory per week; each 40 person lecture splits into two 20 person lab sections; the professor teaching the lecture also teaches the laboratory classes; there are no teaching assistants or markers. Typically there will be ten experiments in a fifteen week semester. Continuity between sections is maintained by the ten common problem sets, the laboratory experiments, the laboratory exam, and the common final exam; this exam is graded by all professors as a team.

## ADMINISTRATION OF THE TEST

At the start of the September semester of 1987 there were about 450 students in the 11 sections of introductory physics 111, and 170 students in four sections of mechanics 101. The test was given within the first two weeks of the semester. After the scores of students who dropped out, and other incomplete data, were removed from consideration, correlations between the grade in the test and final grade in the course were obtained for 343 students in introductory physics 111 and 119 students in mechanics 101.

In earlier semesters the test was given as a pre-test to 63 students in introductory introductory physics 111, 80 students in mechanics 101, and to 38 students in waves and optics 301; and as a post test to 61 students in introductory physics 111, 56 students in mechanics 101, and 35 students in waves and optics 301.

The test was also given to the three physics classes in a feeder high school that had five hundred students. Twenty one students were taking a PSSC type course while thirty six were taking the general physics course.

When administering the test it was stressed that the results would not directly affect the grade in the course, but that if students wished the researcher would be pleased to go over the test with them privately and that in this way they might identify areas where they did not have a good understanding of mechanics. This resulted in interviews with a cross-section but not a random selection of the college students. ( Students in courses that were taught by the researcher could speak to another professor; no professor saw the scores for his class until after the end of the semester).

For the John Abbott College results it is important to note that the pre-test and post-test scores refer to different classes at different times and not to the same class being tested twice, as was the case for Halloun and Hestenes.

TABLE 1

RESULTS OBTAINED IN THE MECHANICS DIAGNOSTIC TEST

| Number of S's | PRE-TEST mean ± std dev | POST-TEST mean ± std dev | Date |
|---|---|---|---|
| **HIGH SCHOOL** | | | |
| 21 PSSC | 15.5 ± 4.1 | | Jan 87 |
| 20 Regular | 12.8 ± 3.3 | | |
| 16 Regular | 12.7 ± 2.8 | | |
| **PHYSICS 111** | | | |
| 343 | 16.5 ± 5.2 | | Sept 87 |
| 63 | 14.1 ± 5 | | Jan 87 |
| 61 | | 16.1 ± 5 | Dec 86 |
| **MECHANICS 101** | | | |
| 119 | 18.8 ± 6.2 | | Sept 87 |
| 80 | 16.9 ± 5 | | Jan 87 |
| 56 | | 20.0 ± 6 | May 87 |
| **WAVES AND OPTICS 301** | | | |
| 38 | 17.4 ± 6.7 | | Jan 87 |
| 35 | | 20.0 ± 5.3 | May 87 |

# TABLE 2

## RESULTS OF HALLOUN AND HESTENES

Table I. Average diagnostic test results by course and professor. Maximum Scores: 36, for the physics diagnostic test; 33, for the mathematics diagnostic including five calculus items which were omitted in College Physics.

| Professor | Number of S's | Math Pretest Mean (s.d.) | Physics Pretest | Physics Post-test | Physics Gain |
|---|---|---|---|---|---|
| | | | **University Physics** | | |
| A | 97 | 17.25 (5.37) [52%] | 18.47 (5.29) [51%] | 23.23 (4.94) [65%] | 4.76 [13%] |
| B | 192 | 16.80 (6.21) [51%] | 18.39 (5.14) [51%] | 23.13 (4.81) [64%] | 4.74 [13%] |
| C | 70 | 19.56 (5.81) [59%] | 18.06 (5.95) [50%] | 22.91 (5.81) [64%] | 4.85 [13%] |
| D | 119 | 17.45 (6.37) [53%] | 19.10 (6.26) [53%] | 22.92 (6.57) [64%] | 3.82 [11%] |
| | | | **College Physics** | | |
| E | 82 | 10.48 (4.58) [37%] | 13.48 (5.00) [37%] | 19.00 (5.16) [53%] | 5.52 [15%] |
| E | 196 | 10.19 (4.51) [36%] | 13.33 (5.09) [37%] | Not Available | |
| F | 127 | 9.75 (4.38) [35%] | 14.43 (5.16) [40%] | Not Available | |
| | | | **High School Physics** | | |
| G | 24 (honors) | | 10.96 (3.28) [30%] | 18.88 (5.02) [52%] | 7.92 [22%] |
| G | 25 (general) | | 10.83 (3.85) [30%] | 15.80 (4.34) [44%] | 4.97 [14%] |

## DISCUSSION OF RESULTS

### COMPARISON OF SCORES OF HIGH SCHOOL STUDENTS

The test was given to the 57 high school students about 8 weeks after the start of their first formal course in physics.

On a 36 question multiple choice test with five distractors per question the chance or random score would be 7.2; at 12.7 and 15.5, the scores are significantly above this.

The difference in the scores of the PSSC and Regular students is significant at better than the 0.01 level. ( the two tailed t ratio is 5.4; for 50 degrees of freedom a ratio of 2.68 is significant at the 0.01 level)

The pre-test scores of both the honours and regular students were found to be the same in the Arizona study. That the scores of the high school students is between the pre and post Arizona scores is consistent with the timing of the test.

TABLE 3

Comparison of High School Results

| Québec | | Arizona | | |
|---|---|---|---|---|
| H S test | | H S pre-test | | H S post-test |
| PSSC | 15.5 ± 4.1 | Hons | 10.96 ± 3.28 | 18.88 ± 5.02 |
| Reg | 12.7 ± 3 | Reg | 10.83 ± 3.85 | 15.80 ± 4.34 |

The screening of the local high school, or the self-selection made by the students when selecting their physics course, could be responsible for the difference in the scores obtained by the PSSC and Regular students. It is also possible that the methodology and course content of the PSSC course had a greater impact on the concepts of the students in the eight weeks between the start of the course and the writing of the test; all of the classes were taught by the same instructor.

## COMPARISON OF INTRODUCTORY PHYSICS 111 SCORES WITH THE ARIZONA COLLEGE RESULTS

Because of the entry requirements and course content it was felt most appropriate to compare the scores obtained by the introductory physics classes with those of the Arizona college physics students.

The test was first given to a John Abbott introductory physics class in the fall of 1986 after two thirds of the course had been given but before college-level study of kinematics; the average score of 16.1 was significantly higher than the 13.7 of the Arizona college pre-test yet below the 19.0 of the Arizona post-test.

TABLE 4

Comparison of Introductory Physics and Arizona Results

| JAC | Arizona | |
|---|---|---|
| Introductory physics all results | pre-test | post-test |
| 16.1 ± 5 | 13.7 ± 5 | 19.00 ± 5.16 |

It was thought that the higher scores of the Abbott students relative to those of the Arizona college students might be due to either the instruction in optics and electricity, or to the problem solving orientation of the course, ( both of which would hopefully improve their ability to read and extract relevant information from the questions) or to the fact that only 45% of the Arizona students had taken physics at school.

However the subsequent pre-test and post-test results agree within one standard deviation with the earlier results and also show no difference between the students who were repeating the course and those who were taking the course for the first time, in agreement with the observation of Halloun and Hestenes. (In the winter semester typically over half are repeating the course.)

TABLE 5

Comparison of scores of Introductory Physics 111 students taking the course for the first time with those repeating the course

| Prof | Number of S's | first time | repeat | combined |
|---|---|---|---|---|
| A | 15 | 15.5 ± 5.2 | | |
| | 20 | | 15.4 ± 6.1 | |
| | 30 | | | 15.3 ± 5.4 |
| B | 15 | 13.8 ± 5.1 | | |
| | 13 | | 12.8 ± 5.1 | |
| | 28 | | | 13.3 ±4.9 |

It would appear that the difference between the local average score and those reported by Hestenes reflects the fact that all the local students have passed high school physics while only 45% of the Arizona college students have done so.

That the average scores obtained by the introductory physics 111 college classes and the PSSC high school classes are the same indicates that the students enter these courses from a common point in terms of their ability to reason and their conceptual framework. This supports the ad-hoc admissions policy of the college that treats students who do well in PSSC physics at school as equal to those who have passed the introductory physics college course.

RESULTS FOR MECHANICS 101

The results for mechanics 101 can be compared with the university physics post-test results of Hestenes because: mechanics 101 is similar to the mechanics part of a typical first year university course in that the same material is covered, but at a pace that spreads the curriculum over one whole semester, and students are taking calculus at the same time. The text we now use, Serway-PHYSICS for SCIENTISTS and ENGINEERS, recognizes the reading level, and the maturity of the students. It is a less sophisticated book than Tipler-PHYSICS the text used by the Arizona students and formerly used at John Abbott College. The reading level and general tone of Serway are better suited to the first semester CEGEP student than those of Tipler, but the book is less satisfactory for the final semester because the students mature noticeably over the three semesters.

The average pre-test score of the mechanics 101 students is 18.0 ± 6 which agrees with the pre-test score of the Arizona university students of 18.5 ± 5, indicating that the two groups are comparable in terms of reasoning and conceptual development.

The higher post-test score of the Arizona students can be attributed to the self selection of the students, and to the greater scope and depth of the first semester of the full year course compared with that of the one semester course at John Abbott.

Given the timing of the testing and the course of study it seems appropriate to say that the Abbott results are consistent with the Arizona data.

Both sets of data show that conventional instruction does improve the conceptual framework of students, even if by only a modest amount.

The averages are;

Table 6

Comparison of mechanics 101 and Arizona university scores

| | pre-test | post-test |
|---|---|---|
| JAC 101 | 18.0 ± 6 | 20.0 ± 6.0 |
| Arizona | 18.5 ± 5 | 23.1 ± 5 |

## RESULTS FOR WAVES AND OPTICS 301

The test was given to one class of waves and optics students as a pre-test at the start of the semester and to the other group at the end of a different semester.

One must be careful in making comparisons between these two groups because the "pre-test" class had had a summer vacation, one semester of electricity and magnetism, then the Christmas vacation in which to " forget " mechanics. The "post-test" class on the other hand had completed the electricity course, or in some cases the mechanics course, in the immediately preceding semester. In addition it should be noted that a significant number of students (13 out of 38 ) in the first group did not complete the questionnaire in the time allotted-35 mins- and this may have depressed the overall average ( 17.4 ). The average mark of the 25 students who did complete the questionnaire was 20.3 ± 6, the average mark of the whole class when only the first 20 questions was scored was 20.4 ± 5 (adjusted to be a mark out of 36 ). Certainly these older students were reading and questioning the wording more than the younger students had, and while these marks are both higher than that of the class as a whole they are within one standard deviation. The average for the "post-test" class was 19.97 ± 5.32 which agrees with that of the "pre-test" class if we make allowances for the time pressure experienced by the first class.

## RESULTS OF INTERVIEWS WITH STUDENTS

In talking with students it was clear that many of them believed that, " constant motion requires constant force ". This, so called, " Aristotelian" idea is one of the most common alternate conceptions held by students and it is probably this one more that any other that has been instrumental in arousing the current interest in the field (see for example the discussion and references in McDermott's review article (1984)).

The students used concepts like energy and momentum wrongly. It was as if they believed that by incorporating enough of the powerful and magical vocabulary of physics into their explanations all difficulties could be overcome. For example they would say ,

> "when the momentum is all used up the ball will start to fall down",
>
> or , "the force of the throw acts until the energy is used up and then it starts to slow down".

Other investigators have recorded such statements (Osborne 1980). In this manner at least, our students act similarly to their counterparts in other continents and in other (western) cultures.

The similarities between our students and college students in Arizona is not too surprising. The similarities between anglophone and francophone CEGEP students and those in France (Viennot 1979), and Australia and New Zealand (Osborne & Freyberg 1985), with their more divergent educational traditions, leads one to suggest that not only is science independent of culture, but so too is the learning of science independent of culture.

The findings also lend weight to the statement made by Caramazza et al in 1981,

> "the results we have reported lead to the conclusion that simple real world experience with moving objects does not lead naturally to the abstraction of principles that are consistent with the formal laws of motion".

## RESULTS OF A PARTICULAR QUESTION

Insight into the effects of traditional teaching on the mechanics concepts held by students is obtained by examining the answers to one of the questions of the test.

Question three is about the forces acting on a ball thrown up into the air when air resistance is neglected. The question is simple to state and it could be expected that everyone must have had the experience of throwing a ball and therefore could understand what was asked.

Question 3

[ --A ball is thrown straight up into the air, neglecting air resistance---]

; On its way up what force(s) act on the ball?

(a) Its weight,vertically downward.

(b) A force that maintains the motion,vertically upward.

(c) The downward weight and a constant upward force.

(d) The downward weight and a decreasing upward force.

(e) An upward force,first acting alone on the ball from point A to a certain higher point, beyond which the downward weight starts acting on the ball.

The question goes to the core of our understanding of preconcepts.

The spontaneous reasoning that is revealed by the answers to this type of question has been well documented ( for example Viennot, 1985).

The correct response is (a) the acceleration due to the force of gravity is independent of the direction or magnitude of the velocity.

In the minds of many, however, there is an identification of the force acting on the ball with the velocity rather than with the acceleration. Thus the decreasing upward force that is preferred by most students. It has been customary to refer to such a conceptual framework as Aristotelian; but the schema of the students is not as consistent as was Aristotle's and is probably closer to the impetus theories of such medieval scholars as Buridan (see for example Gunstone & Watts 1985). Recently Viennot (1985), who was one of the first to examine such misconceptions, has written about the difficulties of interpreting such "wrong answers" given by college students in terms of the carefully phrased definitions of physics.

From Table 9 one can note that the percentage of students choosing the correct answer rises with instruction - regardless of the subject matter of the course! Does this indicate that only students having a good conceptual understanding of physics survive to take the more advanced courses? Or does instruction improve the

TABLE 9

Response to Question Three

| Course | | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | # of students | % choosing (a) | % choosing (d) | % choosing (a) | % choosing (d) |
| Intro to Physics | 424 | 10.8 | 63.2 | | |
| 111 | 61 | | | 21.6 | 45 |
| Mech 101 | 134 | 21.6 | 53.7 | | |
| | 56 | | | 51.8 | 31.6 |
| Waves /Optics | 38 | 39.4 | 39.4 | | |
| 301 | 35 | | | 45.7 | 37 |

students' ability to understand what was asked, and to reason through to the appropriate answer of the multiple choice test?

One can also see from the table that the percentage of students choosing the correct answer peaks at the end of the mechanics course. But are we really successful when only about 50% understand correctly at the end of the mechanics course, and only about 45% retain that understanding through the subsequent course?

This is a graphic demonstration of the difficulty of encouraging students to change their schema, their self consistent explanation for the workings of the world. We can take some comfort that this change induced by the mechanics 101 course has at least persisted into the waves and optics 301 course even if the overall score in the test did not.

Recently, Hestenes (1987) and Rosenquist & McDermott (1987) have examined the poor effectiveness of traditional instruction in changing the concepts held by students .

## COMPARISON WITH THE RESULTS OF DESAUTELS

In 1984 Pierre Desautels administered his eleven item test on uniformly accelerated motion to students in mechanics 101, and in waves and optics 301. The tests are different but comparisons can be made between some items and his results agree with mine in three ways:

the average score was low;

the score improved after a conventional mechanics course;

there was only a small falling off in the score obtained at the end of the mechanics 101 course compared with that obtained while taking waves and optics 301--one year of maturity had not improved the students' understanding of uniformly accelerated motion.

In addition he showed that the use of his computer simulation in course 101 produced a greater improvement in the pre vs post 101 score compared with the change produced by a conventional course.

He noted that his eleven questions could be divided into two groups; there were those that involved situations with which the students had had concrete experience and could relate well to, for example,

" a cyclist coasting down an incline "

The other kind were those such as,

" an apple is thrown up with a certain speed then a second is thrown up in the same way but with twice the speed of the first ",

where there was less direct experience with the critical features of the problem. The performance on this second type of problem was much worse:

He notes that when a student watches a glider moving along an air track the motion is completed in a fraction of a second but the analysis may take hours. It was to increase the students concrete experience with the physics of such phenomena rather with the analysis of data that a computer simulation using sprite graphics was developed.

In 1984 Desautels administered his questions to a control group of 104 students before and after they took the conventional mechanics 101 course, and subsequently to 73 students in waves and optics 301.

There is very little difference between the pre and post scores of the mechanics 101 students. However when the five questions that dealt with topics that were to become the subject of the computer simulation were examined separately there was a significant difference; the score in his test improved from 21% before the students had taken mechanics 101 to 31% after they had taken the course.

Table 7

Comparison of John Abbott results and those of Desautels

| course | # of students | pre-test score % | post-test score % |
|---|---|---|---|
| **1984 results of Desautels control group that received conventional instruction** | | | |
| 101 | 104 | 40.9 | 42.6 |
| 301 | 73 | 37.8 | |
| **John Abbott Scores results of the H & H test** | | | |
| 101 | 119 | 52.2 | |
| | 56 | | 55.5 |
| 301 | 38 | 49.1 | |
| | 35 | | 55.5 |

The results of Desautel agree with those of this study in that the score achieved in a test designed to measure understanding of mechanics concepts improved slightly after conventional instruction in mechanics 101 but had then declined when measured prior to the waves and optics 301 course, as is shown in the table above.

A different group of one hundred and eleven students were subsequently tested before and after they followed a mechanics 101 course that included the computer simulation. While the initial score obtained by the group in his test was much lower than that of the control group, when the results of just the 5 questions addressed in the simulation were examined the improvement was much greater.

## CORRELATION BETWEEN SCORE IN THE TEST AND GRADE IN THE COURSE

The results of this study agree with those of Halloun and Hestenes in that performance in the test is consistent across different classes. There is a difference of about one standard deviation between the score obtained by the introductory physics 111 students and the post test score of the mechanics 101 students. Score on the test improves with instruction.

However the grade a student achieves in a John Abbott physics course depends mainly on his or her ability to solve problems rather than on conceptual understanding.

To test this hypothesis, and to determine whether the test could be used as a placement test for mechanics 101, a linear regression analysis was done for the score in the test and grade in the course for the 343 students in introductory physics 111 and the 119 students in mechanics 101 who wrote the test in September of 1987. The correlation coefficients were 0.272, and 0.207 respectively, indicating that the understanding that is tested by the mechanics preconcepts test accounts for only 7% ( $0.272^2$ ) of the grade in the introductory physics course and even less, 4%, of the grade in the mechanics course.

These very low correlation coefficients confirm that the problem solving nature of the courses do little to foster understanding of physics concepts.

Even though the difference between the average scores of 16.5 for the 343 students in introductory physics and 18.8 for the 119 students in mechanics who wrote the test in September of 1987 is significant at better that the 0.01 level ( the two tailed t ratio is 3.94 ) the test in itself would not be a useful predictor of performance in mechanics 101.

This agrees with the findings of Halloun and Hestenes who found that the test alone was not as good a predictor of performance as was the combination test score and the score in a mathematics test.

Champagne and Klopfer ( 1982) examined the causal relationship between success in an introductory college physics course and three variables: mathematical aptitude, " Newtonian physics variable", and previous science experience as measured by high school and college courses followed and passed.

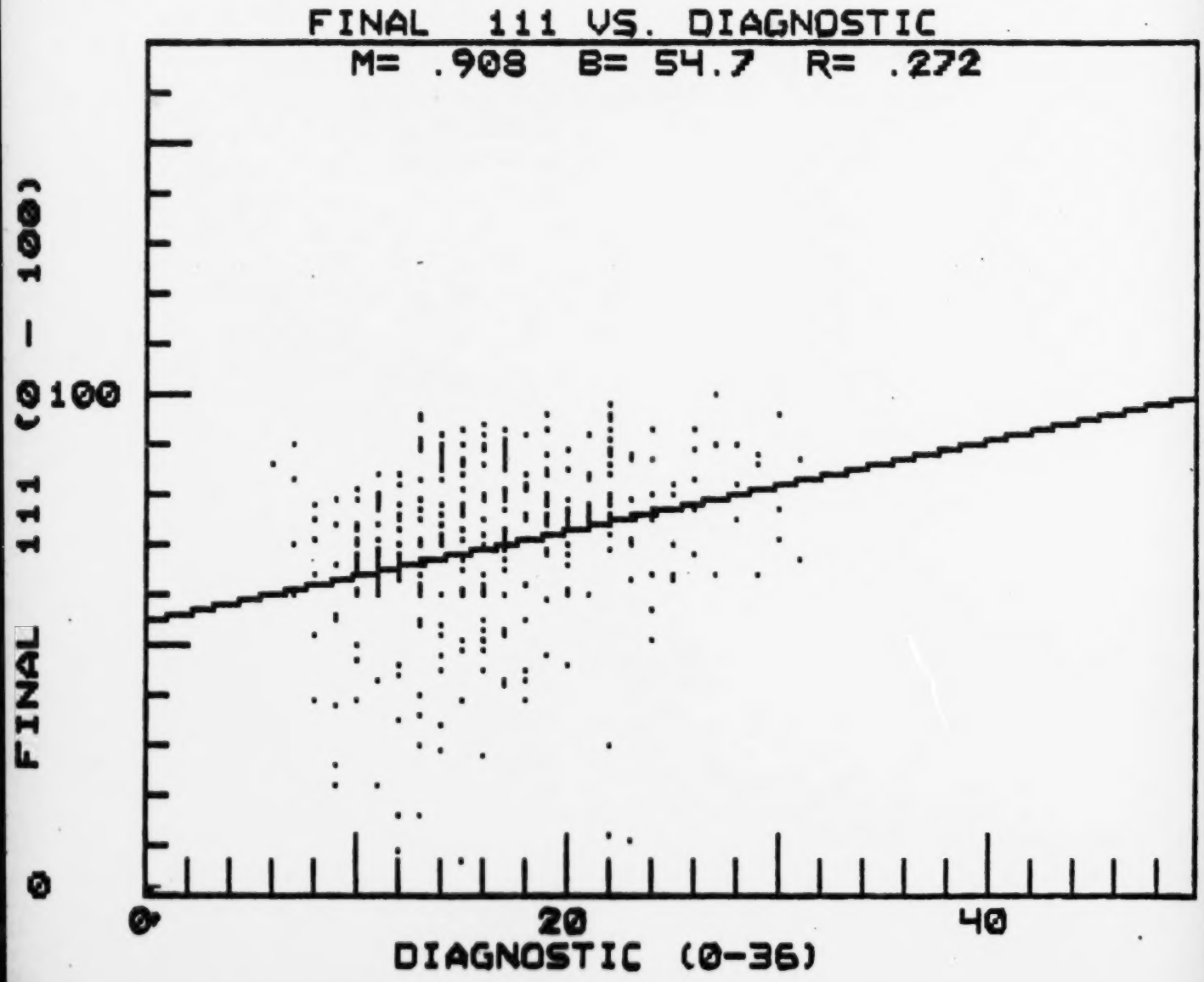
For their sample of one hundred and ten students they found that previous science exposure had almost no effect. Their "Newtonian physics variable" was a combination of preconcepts of motion knowledge and formal reasoning ability ( in the sense of Piaget's stages of intellectual development). They found that about

one third of the students success could be predicted on the basis of the two important variables.

Wollman and Lawrenz ( 1984) approached the problem from the opposite sense; identifying potential drop-outs. But their results are relevant to the John Abbott situation in that they too found that looking at only one variable - they used math ability and more general indicators such as total grade point average - is less reliable than combining several indicators.

The scatter plot for the 111 results is shown in figure 1.

FIGURE 1



## CONCLUSIONS

Applying the test of Halloun & Hestenes has provided insight into the preconcepts, knowledge, and understanding about physics, of John Abbott College students.

In summary the five research questions that were examined reveal that;

1. The conceptual knowledge of the Québec high school students who were tested was found to be consistent with that of the Arizona high school students.

2. For both the John Abbott College students and the Arizona university and college students conventional instruction does little to improve their understanding of mechanics concepts. What growth in understanding did occur for the John Abbott students peaked at the end of the mechanics course and subsequently declined somewhat.

3. The mechanics scheme held by most John Abbott students is comparable to that held by students in other countries, in other cultures. It would seem that not only is physics independent of culture but so too is the learning of physics.

4. The results of Desautels reinforce this conclusion and show that in Québec language of instruction does not affect the development of the students understanding of the conceptual framework of mechanics. For both English and French speaking students conventional instruction does little for their conceptual development.

5. By itself the mechanics preconcepts test of Halloun and Hestenes would not serve as a placement test for mechanics 101. However the test would be a valuable component when combined with a test of problem solving ability and of mathematical skills.

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